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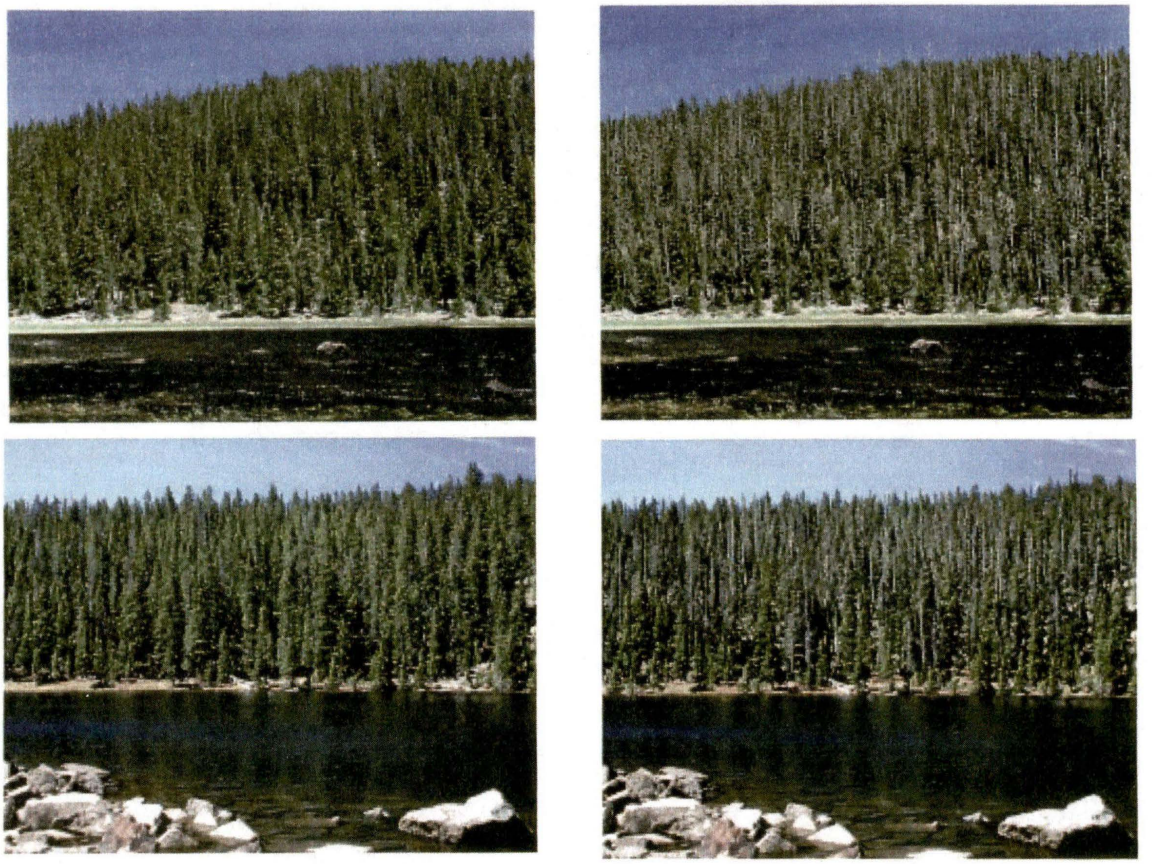

Visualization of forest management issues on the Dixie National Forest

Final report
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VISUALIZATION OF FOREST MANAGEMENT ISSUES ON THE DIXIE NATIONAL FOREST

FINAL REPORT

USDA Forest Service
Region 4, Ogden, Utah

Principal Investigator:
Brian Orland

SUMMARY

The Imaging Systems Laboratory at the University of Illinois has assisted USDA Forest Service, Region 4 Forest Pest Management and the Dixie National Forest in exploring the use of computer-based data visualization for communicating a variety of potential insect and timber management impacts in the Cedar City and Teasdale districts. A set of visualizations has been created to represent the historical development, predicted future conditions, and effects of potential management responses to spruce beetle outbreaks. The visualizations promise to help forest managers address public concerns regarding the visual impacts of insect damage and treatments. To accomplish these goals it was necessary to establish the accuracy of the resulting imagery by reference to current forest databases and models. The validity of the tools has been investigated through systematic studies of public judgments based on the images.

Background

In the early 1920s a devastating spruce beetle outbreak killed the majority of standing timber on the Boulder top area in the Teasdale district of the Dixie National Forest. Very few large trees were left standing; only those less than about 4" dbh escaped destruction. Recovery from that outbreak has proceeded up to the present with increasing maturity and growth of those once-small trees. In the next thirty to forty years the forest may reach stocking levels deemed to represent high hazard for spruce beetle damage. Action is needed to inform and evaluate possible management responses to that hazard.

The Midway Face area did not suffer extensive damage in the 1920s but is currently at a stocking level deemed high hazard. The area consists of a mature Englemann Spruce-Subalpine Fir forest with many trees greater than 40 inches diameter and one hundred feet tall. Action is needed to evaluate potential insect damage and inform public and management responses (Munson and DeBlander, 1992).

The area is one of great sensitivity. Some of Southern Utah's greatest natural resources are its scenic landscapes and recreation opportunities. The study area stretches from Capitol Reef National Park in the East to Zion National Park in the West. Cedar Breaks National Monument and Bryce Canyon National Park are other internationally renowned scenic attractions adjacent to the Dixie National Forest. Highways through the Dixie National Forest carry millions of visitors each year, the forest providing the setting and backdrop for numerous outdoor activities. The future condition of the forest is critical to maintaining a high level of scenic quality and hence there are high expectations of forest management.

Loss or degradation of timber and scenic resources due to insect pests are common problems in the national forest system. The impacts are highly visible, frequently resulting in extensive acreages of defoliated or dead trees. The response mechanisms, unfortunately, can also lead to significant impacts on forest scenery, treatments including such measures as prescribed fire, and silvicultural measures including reduction of basal area in affected areas.

These problems are not peculiar to the Dixie National Forest. To address such problems a number of agency groups and researchers have developed computer systems to aid managers and public groups in making complex decisions (e.g., Buhyoff et al., 1988;

Daniel et al., 1976; Gernazian, 1989; Heasley, 1990; Orland, LaFontaine and Daniel, 1990). The key aspect to all of these systems has been their ability to share information between more common computer applications such as Geographic Information Systems, Image Processing, Computer Graphics, Database Management, Linear Programming etc. Examples within the national forest system have included IPIAS (Integrated Pest Impact Assessment System, IRMA (Integrated Resource Management Application), and INFORMS (Integrated Forest Management System). Each of these has combined the power of existing growth and yield and insect spread models with the spatial data handling of Geographic Information Systems in systems where the manager can query the data bases and test different management strategies and models.

Trial implementations of these systems on the Nicolet (IRMA), the Nez Perce (IPIAS/ INFORMS), and the Deerlodge (INFORMS) National Forests have proven powerful tools for communication of forest management issues. In the latter instance, in particular, the computer products included graphic visualizations of the anticipated outcomes (Heasley, 1990). However, the products of such systems are still limited in their effectiveness.

First, the graphics output provided remains diagrammatic rather than realistically showing people what to expect, so that its usefulness in the public arena has been limited. In any event, the computing time involved is long enough to restrict use of the tools in interactive testing of ideas and options.

Second, the process of assembling a GIS database requires a several-year commitment on the part of the forest. At this stage few forests have been able to implement GIS databases of the extent, detail and accuracy needed for resource modeling.

Third, even with a detailed GIS, few forests have simultaneously been able to develop and verify the range of resource models needed to drive an integrated management system. Creating models for timber growth and yield or insect pests demands a long-range commitment to data collection and model development.

Finally, there are some components of a multiple resource management system that are frequently absent on individual forests. Public perception models, while essential for management of scenic and recreation resources are not generally available. Model creation and testing, as for timber and pests, is best undertaken at early stages of system development.

Project description

This project implemented visual simulation techniques (Orland, 1988, in press; Orland, Daniel, Lynch and Holsten, 1992), and a public perception modeling component as described by Daniel, Orland, Hetherington and Paschke (1992) all in the context of an intended implementation of the INFORMS management system. The settings for these simulation studies were chosen to represent forest conditions on the Cedar City and Teasdale Ranger Districts of the Dixie National Forest.

Specific tasks:

1. The Imaging Systems Laboratory at the University of Illinois developed a workplan in cooperation with forest staff to specify collection of "calibration" images which were used to guide development of simulations. Calibration photos were collected under careful control of photographic location, direction, and time-of-day. They represented the range of impacts and recovery conditions to be met in the postulated insect damage and management scenarios.

2. The Imaging Systems Lab collaborated with forest staff to identify precise locations of study sites, to collect calibrated ground photography to support simulation activities, to assist in preparation of flight plans for aerial video runs by FPM-MAG, and to assist in coordinating data acquisition and preparation by Forest Service staff.

3. Visual simulations were provided of expected insect damage scenarios at locations on Boulder Top and Midway Face: Simulated conditions generally followed a pattern of +one, +five, +ten, +twenty, +forty, and +sixty years from present.

4. Visual simulations of management alternatives and their expected impacts were to be developed for the same locations: Simulated conditions generally followed a pattern of conditions immediately post-management activity, +one, +five, +ten, +twenty, +forty, and +sixty years from present.

5. Development of a public perception model addressing insect impacts and management responses was initiated. Implementation of a full public perception model would need to be a multi-year commitment of resources and was not covered by this project. However, work taking place under this agreement was done to support such model development. This project included allowance for planning

activities and a joint meeting between the sponsors, the Imaging Systems Laboratory at Illinois, and Dr. Terry Daniel of the Environmental Perception Laboratory at the University of Arizona. Pilot studies were conducted using simulations from this study and are reported here.

6. Image development work was conducted in the context of a proposed integrated resource management system for the Dixie National Forest based on the INFORMS model. Implementation of INFORMS would be a multi-year commitment of resources and was not covered by this proposal. This project included allowance for planning activities which included a joint meeting between the Imaging Systems Lab at Illinois, and Dr. Doug Loh of the STARR Lab at Texas A&M University.

Resources provided by the Dixie NF/FPM-MAG:

The following tasks were undertaken by the Dixie National Forest, assisted by Region 4 FPM and the FPM MAG group in Fort Collins:
Forest data collection; assistance with development of insect damage and treatment scenarios; aerial videography and photography; stereo plotting; conducting PROGNOSIS projections; on-site consultation in Illinois.

Imaging Systems Laboratory and personnel

Image simulation activities were undertaken by personnel under the guidance of Professor Brian Orland, Research Associate Jeanine Paschke, and other staff in the Imaging Systems Laboratory, Department of Landscape Architecture, University of Illinois at Urbana-Champaign. The computing facilities of the Imaging Systems Laboratory were used for the project.

The lab was established in 1986 to conduct studies in environmental perception based on manipulated photographic images. Since that time the lab has undergone continuous expansion, has upgraded equipment, evaluated and adopted new technologies, and in some cases developed new techniques to address specialized problems in image development. A description of the lab is attached as an Appendix.

STUDY APPROACH

Initial ground data collection for the study occurred in summer of 1991, interpretation, data analysis, and image manipulation occurred from Fall 1991 to Summer 1992, public perception studies were conducted in Fall, 1992 and the results presented in January, 1993. For simplicity the study is divided into two sections: Study sites on Boulder Mountain in Teasdale district — Purple Lake, Surveyor's Lake, and Pleasant Creek; and a study site on Midway Face in the Cedar City district.

Study site selection

Because of the practical difficulty of creating calibrated sets of images for multiple locations it was necessary to restrict the study sites to just four. Two principles guided the choice of study sites. First, two sites were chosen for their particular locations. The location at Midway Face was chosen for its prominent position facing the junction of Utah Highway 14 and the Highway 148 turnoff to Cedar Breaks National Monument. The Purple Lake location was chosen because historic photography existed for that location and afforded the possibility of validating the development of vegetation predicted by a forest growth model. Second, sites were chosen to represent the range of conditions found within the two districts. Choices were made by the investigators in conjunction with forest staff.

DATA COLLECTION

Photo survey

Field work took place in June 1991. Site photography of the four key locations followed Orland's (1988) guidelines to ensure high color quality for computer image scanning. In addition, extensive contextual photography was collected from other locations throughout the Dixie National Forest to provide guidance for the subsequent visual editing of images to create visualizations of alternative management scenarios. This latter photographic record provided the means to "calibrate" predicted visual patterns to known conditions on the ground.

Prompted by previous experience, an aerial survey of the Bouldertop area was accomplished and 35mm oblique photography was collected to strengthen the spatial arrangement records of the ground photography. Further photographs were taken in fall, 1991, and summer, 1992, to create a record of the landscape context needed for the perceptual survey portion of the project.

The FPM Methods Applications Group (MAG), flew medium altitude 9x9in aerial photography and aerial video at 0.5ml altitude to provide data for later vegetation and spatial analyses.

Stand exams

For each stand represented in the four study scenes a detailed exam was conducted, based on 0.25 acre plots. In the case of Midway Face this exam was supplemented by a detailed pest analysis (Munson, 1992), and a detailed stem map developed by MAG from stereo analysis of the aerial photography.

The Purple Lake location also offered a special case situation. Because of the remoteness, high altitude (11,000ft), and dryness of the location, most of the trees killed in a 1920 outbreak of spruce beetle were still evident on the ground. Stumps were quite apparent and still sound, enabling the study team to "reconstruct" the composition of the forest in 1920 and use that as a starting point for growth modeling. Cores were taken of older live trees on site to confirm the year of the outbreak — that date was marked by subsequent release of the few remaining trees. Growth rate was also indicated by those cores and the current size of these older trees.

Forest growth and development

Growth modeling was conducted by staff of Region 4 using a Utah variant of PROGNOSIS. Growth and development data available for the Purple Lake location was used to calibrate the Utah variant to the relatively high productivity of these southern Utah sites. Predictions of forest composition by species and size class were calculated for ten-year increments from 1920 to 2100AD.

Data interpretation

The difficult synthesis of visual and forest composition data was accomplished by a series of intensive workshop sessions involving forest and Imaging Systems Lab personnel, some on site in Utah and others in the lab in Illinois.

Image manipulation techniques

The techniques employed in this study refined and evolved from those used in previous work. Three main graphic techniques were used:

Image processing

To represent color changes accompanying early stages of tree mortality the green and grey coloration of healthy and dead trees were analysed. The mathematical relationships between picture element color values in the two conditions was then used as a filter to represent the visual effect of tree mortality in previously healthy scenes. The approach has been used extensively and can be found described in more detail in the context of Western Spruce Budworm damage in mixed conifers (Orland et al., 1992; Orland, in press) and Spruce Beetle damage in Alaskan spruce forest (Orland, LaFontaine and Daniel, 1990).

Pattern sampling

The effects of advanced mortality where trees lose entire limbs, of catastrophic fire, or of silvicultural treatments, cannot be represented by color changes alone. To address this issue a sampling method was used whereby, for example, the visual patterns created by exposed snags in a forest canopy were captured and then used to represent that effect in other pictures. The application in this project was directly derived from its use in visualizing the recovery of Spruce Beetle devastated and burned landscapes in Alaska (Orland, LaFontaine and Daniel, 1990).

Image editing

This "traditional" use of computer image capture technology represents changes in forest images by simply substituting forest elements from a library of partial images to replace portions of an existing image. For example, new tree images of appropriate size and species can be pasted into an existing scene to represent growth or new planting. Detailed descriptions of this technique can be found in numerous texts (Orland, 1988, in press).

Specific technique development for this project

No new techniques were developed for this project. However, a change was made in the principal computer platform used for image editing. Image processing took place in a PC-DOS environment using Gupta and Orland's (1988) *Toolbox* program. Pattern-sampling and editing tasks were performed on a Apple Mac IIfx principally using Adobe Photoshop software. *Toolbox* was developed specifically for the task of image processing simulation and gives the user a high degree of numerical control over image characteristics. This degree of control was not available through commercially available Macintosh software. On the other hand, the power of Adobe Photoshop for image editing far surpassed that of the PC-DOS software formerly in use. Image files adopted the *.tga format to ensure consistency across computer platforms.

IMAGE CREATION

For typical sequences of visual simulations the stages of development of an insect outbreak result in a series of corresponding visual changes:

a. color changes as insect infestation spreads and trees are killed,

b. structure changes as trees lose needles and became snags, and

c. spatial changes as stands thin due to loss of branches, tree blow-down, and silvicultural treatments.

Each type of change needed a different simulation approach. Techniques proven effective in previous projects were used along with some new approaches. The following sections explain the techniques used.

Color change

At present, color change is the most automated simulation task to perform but it requires extensive ground data collection together with calibration analysis to produce good results. Knowledge gained from previous projects (Carson N.F., New Mexico and Chugach N.F., Alaska (Orland, in press)) aided in establishing proper techniques for color change manipulation. The *Toolbox* program (Gupta and Orland, 1988), developed in the Imaging Systems Lab, was used to analyze and perform filtering processes to simulate the color changes caused by spruce beetle. The first color change is that of healthy green needles turning to a yellow-green color. As the tree becomes more stressed and dies, the needles turn grey. These were the two colors targeted for the simulations (see Orland, Daniel, Lynch, and Holsten, 1992; Orland, in press).

Because each image is photographed under different lighting conditions and at a different time of day, color characteristics vary between images so each image is considered separately. The first step is to analyze the green characteristic of the spruce trees in each image to isolate its digital color signature. Color in this case is a mixture of 3 components of light - red, green and blue, each on its own channel. The system in use for this project was restricted to 32 levels on each channel - 0 being lowest (off) and 31 being the highest (fully bright). Once the range of components is found for the green characteristic, one or all of the channels can be manipulated to change the green trees to the characteristic colors of damage and/or death.

To simplify analysis and manipulation, a color characteristic found in an image, say green, is split into three or more smaller categories - dark green, mid-green and light green. The ranges of red, green and blue components are then identified for each and are referred to here as the "edit" ranges. Colors to be simulated have their own characteristic combinations of red, green, and blue and are referred to here as the "target" ranges.

By analysing both the edit and target colors, a multiplication factor is identified for use in changing the edit colors to the target colors. In this case, the change from healthy green to damaged yellow-green typically called for increasing the red component by a multiple of 1.3-1.7 times the original amount. The blue channel was multiplied by 1.1-1.3 and the green channel by 1.1-1.5. The level depended on the color and contrast characteristics of the original image. By using the multiply method, shades of color identified by the edit range were changed to approximately equal the amount of shades

for the target color.

As the spread of insect feeding galleries kills the tree, the needles turn from yellow-green and eventually fall revealing the grey color of underlying twigs and branches. True grey is an equal combination of red, green and blue. Using multipliers alone would not result in a true grey unless each individual color within the edit range was multiplied separately. This would be very tedious and time consuming. The process in this case was to first change all edit numbers to the same color and then subtract equal amounts from that color to reach true grey. For example, if the edit range for light green was:

R= 9-12, G= 5-13, B= 6-9 (light green)

and the target color is:

R= 17, G= 17, B= 17 (grey)

multiplying by 9 (the highest possible multiplier) will turn all pixels within the edit range white (R=31, G=31, B=31). By subtracting the same amount from each channel, in this case 14, a true grey will result. This technique does produce a truer gray than attempting to find the correct multiplier for each channel of each target range, however it does cause some problems. By doing the multiplication part of the process, various shades of the edit color are being collapsed into one color which reduces the contrast of the image. Because of this, the edit ranges available tend to be finer in this process than in the multiplication only process.

Structure change

Not only does the color of trees change as damage progresses, but first needles then small branches fall and the visible structure of individual trees changes. The photographic database collected for the project contained many examples of the visual character of the forest in these later stages. Dead trees are visible initially as a grey-brown color. With increasing limb-fall they progressively turn to a lighter grey-white and a more open branch structure. By using various painting tools in Adobe Photoshop, custom paintbrushes or "icons" were formed to resemble a tree with bare branches. As the damaged progressed, the icons have less branch detail until eventually they become vertical lines. These icons were applied to the scene using gray colors similar to those found in the examples. Most of the study scenes have a snag or two in them already, so

colors and patterns were readily compared for accuracy.

In the case of Pleasant Creek, a single vertical column of pixels was used for representing a snag. This scene is taken at a further distance than the others which means the individual trees appear much smaller on the screen. At this distance, it would be difficult to discern individual branches. In addition, it is not possible to create custom paintbrushes of the same detail used in the other scenes because the display resolution used at the time of this study (512 x 400 pixels) dictates that individual tree crowns are only a few pixels in size.

Once the shape and color of the snags were identified, the custom brush was used to scatter the icon throughout the image following the pattern of the insect spread (Orland, LaFontaine and Daniel, 1990). It was generally used to "paint" on top of the previous image to follow the insect spread pattern. However, when this is done, the entire tree from the previous image shows through the bare branches. After the snag icon was applied, the area around the branches had to be cleaned up. Shadow and ground patterns from the image were used to "paint" open space around the snags where there once were branches and needles. Detailed information concerning this technique is in the following section.

Spatial change

One of the most important tasks in these simulations was to represent silvicultural practices that may prevent insect spreads from beginning, which in this case called for various patterns and configurations of tree removal. Removing objects from scenes has always been more difficult than adding objects (Orland, 1988). Essentially it is the adding of "space", not the removal of an object that creates the effect. When trees are harvested, space is created where the tree once stood and more shadows appear in the stand. Depending on the vantage point of the image, more ground or sky may also appear as trees are removed. For these scenes ground, shadow and sky patterns were identified and applied with various shapes of paintbrushes throughout the scene where removals were expected.

This technique requires more emphasis on graphic and artistic skills than the others previously mentioned. When space is created in a scene, the light, shadow and perspective must be considered to make the space look "real". This takes a lot of working and reworking to get the light and shadows right. Much research is currently addressing

these issues in the attempt to bring more numeric control to the image-making process. At this time the most efficient way to create images is to rely on human interpreters of the data relationships. The limit to the validity of such images is the expertise of the various specialists involved in the review process.

A total of 46 digital-video simulation images was developed for four selected areas: Purple Lake, Surveyor's Lake, Pleasant Creek, in the Teasel District, and Midway Face in the Cedar City District. Two primary types of simulation sequences were developed for the four scenes: *no treatment* scenarios and *treatment* scenarios. In each case the number of time steps for which images were created was driven by the anticipated biological changes and management interventions under each scenario.

For the Purple Lake, Surveyor's Lake, and Pleasant Creek scenes, six *no treatment* scenes and five *treatment* scenes were developed from the *original* images from each area. In addition, a four scene *retrospective* sequence for the Purple Lake image was developed to parallel a historic progression of photographs showing bark beetle impacts from 1921. For the Midway Face scene, eight *no treatment* scenes and two different *treatment* sequences (T1 and T2) that contained seven and four scenes respectively were developed from the *original* image.

DESCRIPTION OF FOREST CONDITIONS REPRESENTED

Purple Lake:

The area is located on the west side of Boulder Mountain, in the Teasel Ranger District, mid-slope at approximately 9,000 feet elevation. The current basal area of the stands in the seen area is 165 sq. ft. composed of 95% spruce species and 5% fir species.

Under a no treatment scenario, the following sequence of events would be expected:

At one year from the date of photography, a few of the dead snags would have dropped out. At the next time interval, 40 years, most of the dead snags would be gone, with new growth evident throughout the stand and many of the openings now being filled in with new growth. At 45 years, visual evidence of damage begins as a yellowish-green coloration which is scattered throughout the stand in clumps, hitting mostly the older trees. About 20% of the larger trees are affected.

At year 50, the damage which began at 45 years is now greyed-out with additional

damage beginning. 20-30% of the larger trees are now dead and grey. An additional 30% have entered the first stages of damage. Most of the mortality is located in the mid-slope to foreground area where the larger trees are located.

At 90 years into the future, the damaged area now appears as dead snags. Approximately 60-70% of the larger trees have been affected. Finally, at 100 years some additional damage has occurred and some of the dead snags have blown down. New growth has begun to fill in some of the bare spots.

Under a treatment scenario, the following sequence of events would be expected:

A silvicultural treatment which includes individual tree selection thins to 110 sq. ft. of basal area on a 30 year cycle would produce the following scenario:

After one year, a few of the snags evident in 1991 have dropped out. At 15 years, new growth has increased the density to approximately 146 sq. ft. of basal area. At 20 years the treatment begins. One third of the basal area would be removed. Removal would occur with emphasis on larger size classes of trees removed. After 40 years, additional growth now fills in spaces left by the treatment 20 years earlier. At 50 years the area would be thinned again down to 100 sq.ft.basal area. More of the larger trees would be removed at this time.

These following scenes are a reconstruction of events from 1920:

In 1920 this was a healthy stand in much the same condition as today. In 1925 a severe insect outbreak occurred and left 90% of the spruce species dead. In 1948 many of those dead trees still appeared as snags in the landscape. Openings become apparent in the stand. By 1968, some regeneration had occurred, but the dead snags still dominated the view.

Surveyor's Lake

This is a high altitude lake at the north end of Boulder mountain at about 11,000 ft. elevation. The current basal area in the surrounding forested area is 135 sq. ft. per acre.

Under a no treatment scenario the following sequence of events would be expected:

At one year, a few of the old dead snags drop out. At 40 years, most of the snags would be gone and new growth building up the density of the stand. At 55 years insect mor-

tality would begin and groups of larger trees show first stages of damage as a yellowish-green coloration. Approximately 30% of the vegetation would be affected. At 60 years, the trees affected in year 55, along with an additional 30%, appear as grey snags. 20% in the first stages of damage. A total of 80% would have been attacked by spruce beetle. At 90 years, all affected trees would appear as dead grey snags. Some scattered trees remain alive. Openings within the stand might be created by the fall of dead trees. Finally, at 110 years , some snags have fallen creating larger open areas. Eventually, regeneration would occur in the these open areas.

Under a treatment scenario, the following sequence of events would be expected:

A silvicultural treatment which included individual tree selection thins to 110 sq. ft. of basal area on a 30 year cycle was projected.

After one year, a few of the snags have dropped out. At 15 years new growth would begin to increase the density of trees. At 20 years the treatment begins and the stand is thinned to 110 sq. ft. of basal area. Tree removal is conducted uniformly throughout the stand. After 40 years, additional growth fills in spaces left by the treatment 20 years earlier. At 50 years, the area would be thinned again from 162 to 100sq. ft.of basal area . More of the larger trees are removed at this second entry.

Pleasant Creek

Pleasant Creek is in an open depression on the top of Boulder Mountain, facing east at approximately 11,000ft. The current basal area of the surrounding forest is 130 sq. ft per acre.

Under a no treatment scenario, the following sequence of events is expected.

At one year some growth is evident in the foreground. At 30 years, additional growth would be evident in the foreground, some isolated trees affected by insect damage. At 50 years, the evidence of the damage would be more widespread. Pockets of damage occur in groups of trees where the basal area is higher. Within each group, 40% of the trees have been affected. At 55 years, areas hit in year 50 are now grey with an additional 25-45% being currently attacked by bark beetle. At 60 years, all of the affected trees are now grey with 40-50% dead. Some trees in the foreground are also affected. At 90 years, dead trees would appear as snags. Openings created by the dead trees and views into the stand would now be apparent.

Under a treatment scenario, the following sequence of events would be expected:

A treatment including individual tree selection to achieve thins to 110 sq. ft. of basal area on a 30 year cycle would produce the following scenario.

After one year some growth becomes evident in the foreground. At 15 years new growth would increase the density of the stand. At 20 years treatment begins. The stand would be thinned from 162 sq. ft. to 108 sq. ft. of basal area. Tree removal would be conducted uniformly throughout the stand. At 40 years, additional growth fills in spaces left by the treatment 20 years earlier. Growth is also evident in the foreground. At 50 years, the area would be thinned again from 169 to 110 sq. ft. of basal area. More of the larger trees are removed at this time. Some regeneration would be evident in the foreground of the stand.

Midway Face

This scene is located in the Cedar City Ranger District, along a shallow valley paralleling Utah Route 14. The study area faces north adjacent to the junction with Utah 143 from Cedar Breaks National Monument. The current basal area is 200 sq. ft. composed of 70% spruce species, 17% fir species and 13% mortality. The area is subject to an active spruce beetle infestation.

Under a no treatment scenario, the following sequence of events is expected.

At 1 year, damage is presently occurring. Three small centers of damage exist with a few damaged trees scattered throughout the stand. At year 3, the first year's damage has turned grey, while the current damage, indicated by yellowing foliage, is spreading outward from the centers. At year 5, damage continues to radiate out from the centers. The third year damage locations are now grey. Additional damage is scattered outside the main centers. At year 8, the damage continues to spread. Older affected trees appear as snags. At year 10, damage would continue to spread, affecting the older spruce. At year 15, damage is still spreading. Openings are evident in the foreground because of loss of density and trees falling. At year 40, some dead trees along the ridgetop have blown down and openings appear along the skyline. At year 60, regeneration that would have begun in the foreground openings would now be visible.

Under the first treatment scenario, the following sequence of events would be expected:

A silvicultural treatment including a sanitation thin of the currently damaged trees in groups, would produce the following scenario. The cutting is done on a ten year cycle.

At year one the current damage centers are evident. At year three, the original centers of the damage are removed. At year 7, larger areas are cut as damage radiates out from the centers. At year 10, damage is still occurring. At year 20, cuts continue to radiate out from the centers with some additional new cuts appearing. At year 40, openings in the upper slope begin to fill in. The spread of damage has discontinued by this time. At year 60, growth continues and the cut areas become less visible.

Under the second treatment scenario, the following sequence of events would be expected:

An alternate silvicultural treatment was developed for this area. It would combine the removal of currently damaged areas along with an individual selection thin conducted uniformly throughout the stand. Thinning would occur on a 40 year cycle.

At year one the currently damaged centers are removed using a small group cut technique. The remainder of the stand is thinned by 40% of the basal area. At year 35, the stand is gaining density and the pockets begin to fill in. At year 40, the stand is thinned evenly down to 120sq. ft. basal area. At year 75, the basal area has returned to approximately 180 sq. ft. and some of the openings in the foreground have filled in with regeneration.

Delivery of images

Images exist in a number of formats. They are available as digital files via the Imaging Systems Lab; they have been delivered to the forest as film-recorded photographic color slides; they were compiled into a narrated videotape; and they are presented as prints in the color plates accompanying this report.

PUBLIC PREFERENCE STUDY

The simulation sequences described above formed the basis for an assessment of public perception of the effects of the bark beetle outbreak. This assessment was conducted as a sub-contract to the Environmental Psychology Laboratory at the University of Arizona. All responses were collected from the subject pool of the Department of Psychology at the University of Arizona. Two different presentation formats were used for all participants: *mixed* and *blocked*. In both formats, subjects viewed and rated individually presented scenes on a 10-point scenic beauty scale. However, subjects always participated in the *mixed* format before the *blocked* format regardless of the random order being used within each format condition.

The general pattern of experiment presented a set of 50 color slides (a "run") to small groups of students participating in the judgment activity for course credit. Each slide was presented for between 5 and 8 seconds and the respondents were asked to imagine themselves in the scene and then give each a preference rating on a one through ten scale (Daniel and Boster, 1976).

Mixed

In order to ensure value estimates of the experimental scenes in the context of the conditions typically encountered by a forest visitor, a *mixed* presentation format was initially adopted. This format involved presenting a few scenes from each experimental sequence mixed with unmanipulated or baseline images from the Dixie National Forest. A total of 34 unmanipulated scenes was digitized for presentation.

In order to insure the minimum exposure of subjects to multiple scenes based on the same original a study design distributed scenes across five different random orders of slides for evaluation. In this instance the numerous manipulated scenes for Midway Face became the controlling factor and resulted in a design with four scenes distributed across each of five different random orders or "runs". Hence each run contained four experimental scenes (e.g., *original, treatment, no treatment,* or *retrospective*) from each sequence. Four scenes from the Purple Lake sequence and eight scenes from the Surveyor's Lake and Pleasant Creek sequences were repeated across different runs. A list of the repeated scenes is presented in Table 1.

Purple Lake	Surveyor's Lake	Pleasant Creek
D1NT100	D2T50B	D3T50
D1T20A	D2T40	D3NT50
D1ORIG	D2NT60	D3NT1
D1NT1	D2NT1	D3T15
	D2NT60	D3T20
	D2T20A	D3ORIG
	D2T15	D3T1
	D2NT55A	D3T40

Table 1. Experimental Scenes Repeated Across Random Orders

A total of four scenes from each area was randomly selected for each random ordered run, for a total of 16 experimental scenes per run. A list of the experimental scenes selected for each run is presented in Table 2. These 16 experimental scenes were combined with the 34 baseline scenes to yield a total of 50 scenes per run. A random presentation sequence of the manipulated and baseline scenes was generated within each run.

Mixed Random Order	Purple Lake	Surveyor's Lake	Pleasant Creek	Midway Face
Run 1	D1R65	D2NT90	D3NT50	D4T1-10A
	D1NT90A	D2T50B	D3T1	D4T1-60A
	D1T50A	D2T40	D3T50	D4NT40
	D1R25A	D2NT55A	D3NT30	D4T2-40
Run 2	D1NT40	D2NT11B	D3T15	D4NT8
	D1T1	D2ORIG	D3NT1	D4T1-7
	D1ORIG	D2T20A	D3T40	D4T2-1A
	D1T15	D2NT1	D3T20	D4NT60
Run 3	D1NT45	D2NT90B	D3NT55B	D4T1-1
	D1NT50	D2T15	D3NT60	D4NT3
	D1R45B	D2NT30	D3NT90B	D4NT15
	D1T20A	D2T1	D3ORIG	D4T1-20B
Run 4	D1NT100A	D2T50B	D3T50	D4NT5A
	D1NT1	D2T40	D3NT50	D4NT10
	D1R70	D2NT60	D3NT1	D4T1-3
	D1T40A	D2NT1	D3T15	D4T2-35A
Run 5	D1NT100A	D2NT60	D3T20	D4NT1
	D1T20A	D2T20A	D3ORIG	D4ORIG
	D1ORIG	D2T15	D3T1	D4T1-40
	D1NT1	D2NT55A	D3T40	D4T2-75A

Table 2. Experimental Scenes Selected Per Run

To familiarize respondents with the scenes to be presented in each run, 10 were randomly selected from all of the 50 scenes to serve as preview scenes. Preview scenes allow the subject to observe the range of areas to be rated as well as practice using the 10-point rating scale. The 10 preview scenes were used for all runs. A list of the preview scenes is presented in Table 3.

6
10
13
24
29
35
9
15
18
D1ORIG

Table 3. Preview Scenes in Order of Presentation for Mixed Format

A total of 83 subjects produced reliable responses in the *mixed* format condition. A breakdown of subjects by condition is provided in Table 4. All ratings were reordered and transformed into *Scenic Beauty Estimate* (Daniel and Boster, 1976) values using RMRATE. The values for repeated scenes were averaged across number of presentations.

	Mixed Format	Blocked Format
Random Order		
1	15	28
2	17	25
3	16	14
4	17	
5	18	

Table 4. Subjects Within Run by Format Condition

Blocked

In order to provide value estimates of the experimental scenes relative other experimental scenes of the same area, *blocked* presentation format was subsequently adopted. This format involved presenting a few select scenes from each experimental sequence with

other scenes from the same sequence for all four sequences. Hence, a subject views and rates the scenes from one experimental sequence before rating scenes from another sequence.

For each experimental sequence, a representative sample of the different types of simulations were strategically selected to serve as baseline scenes that remained constant across different random orders or "runs". Four scenes were selected from the Purple Lake sequence, five scenes were selected form the Surveyor's Lake and Pleasant Creek sequences, and six scenes were selected from the Midway sequence to serve as baseline scenes. A list of these scenes is presented in Table 5.

Purple Lake	Surveyor's Lake	Pleasant Creek	Midway Face
D1NT1	D2NT1	D3NT1	D4NT1
D1T15	D2NT11B	D3NT90B	D4NT60
D1R65	D2T1	D3T1	D4T1-1
D1ORIG	D2T50B	D3T50	D4T1-60A
	D2ORIG	D3ORIG	D4T2-35A
			D4ORIG

Table 5. Baseline Scenes for the Blocked Format Condition

The baseline scenes for the Purple Lake sequence included *no treatment*, *treatment*, *retrospective*, and one *original*. The Surveyor's Lake and Pleasant Creek baseline scenes included two *no treatment*, two *treatment*, and one *original*. The Midway baseline scenes included two *no treatment*, two *treatment* 1, one *treatment* 2, and one *original*. The remaining scenes within each experimental sequence were randomly selected for inclusion into one of the three runs.

Random orders were generated within each experimental sequence for each run. Rather than "mixing" experimental sequences by randomization, this procedure allowed a random order of presentation within each sequence. For the *blocked* condition, the presentation of the experimental sequences followed the following order : Purple Lake, Surveyor's Lake, Pleasant Creek, and Midway.

For each run, all of the scenes within one experimental sequence were shown as preview scenes immediately before subjects rated the same scenes in the same random order. In other words, subjects previewed all of the Purple Lake scenes and then rated the same scenes in the same order before moving onto another simulation sequence.

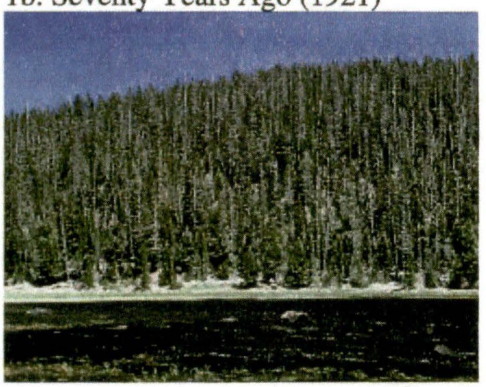
Purple Lake Retrospective - Plate 1A

Due to the unique topographical and climatic conditions of the Purple Lake area, physical evidence remained of a prior spruce beetle outbreak around the turn of the century. Retrospective simulations were created depicting the species and size compositions of the forest beginning in 1920 to present.

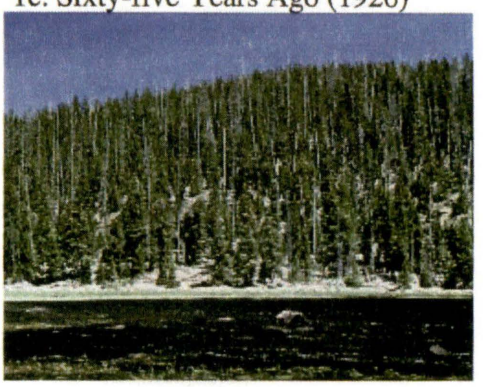
1a. Original Image (1991)

1b. Seventy Years Ago (1921)

1c. Sixty-five Years Ago (1926)



1d. Forty-five Years Ago (1948)



1e. Twenty-five Years Ago (1968)

Purple Lake - Plate 1B

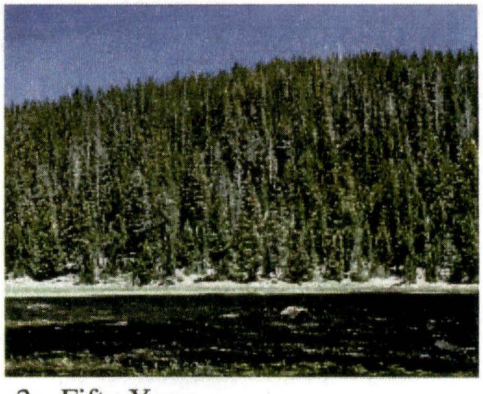
Simulations show progressive changes due to spruce bark beetleinfestation with no management intervention. As the impact of the infestation increases over time, the general coloration shifts from a healthy green coloration to yellow and eventually to dead grey snags.

2a. Orignal Image (1991)

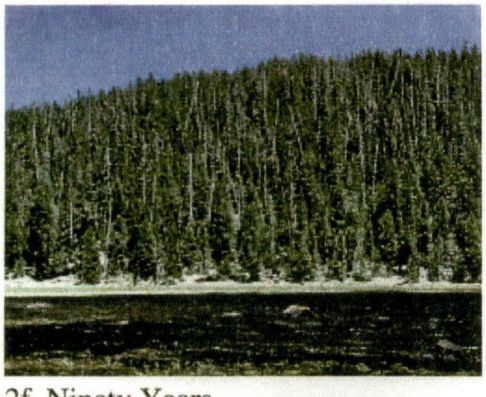
2b. One Year

2c. Forty Years

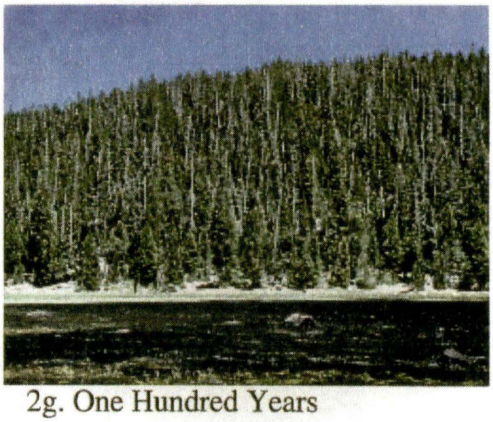
2d. Forty-five Years



2e. Fifty Years



2f. Ninety Years



2g. One Hundred Years

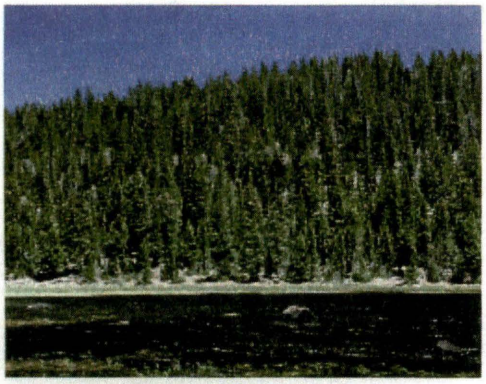
Purple Lake - Plate 1C

Simulations depict forest regeneration from a spruce bark beetle outbreak following management intervention of an individual selection thin to 120 sq. ft. of basal area on a thirty year cycle. The visual characteristics of management intervention focus upon the creation of space to replicate patterns of selective cutting.

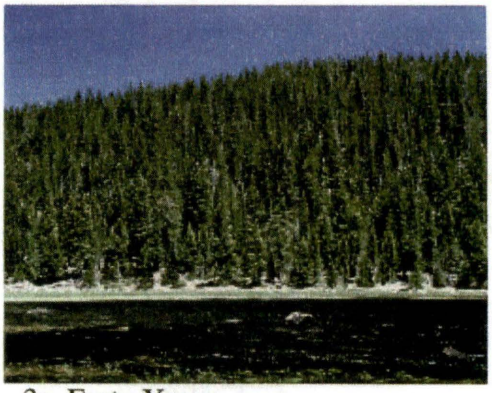
3a. Original Image (1991)

3b. One Year

3c. Fifteen Years



3d. Twenty Years



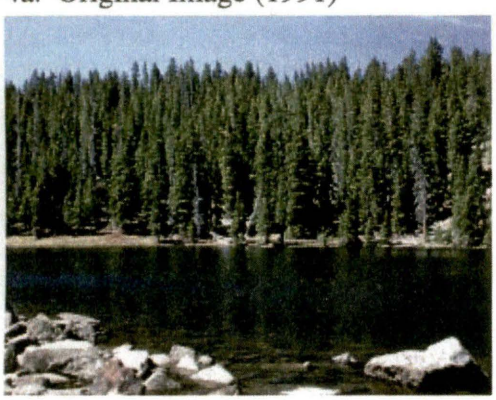
3e. Forty Years

3f. Fifty Years

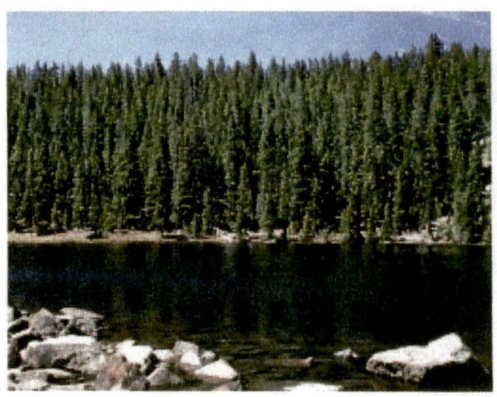
Surveyor's Lake - Plate 2A

Simulations show conditions as the forest recovers from a spruce bark beetle outbreak with no management intervention. The simulation depicting the forest in sixty years illustrates the significant proportion of trees killed by the infestation. This percentage continues to increase with the final simulation depicting a large percentage of dead material.

4a. Original Image (1991)

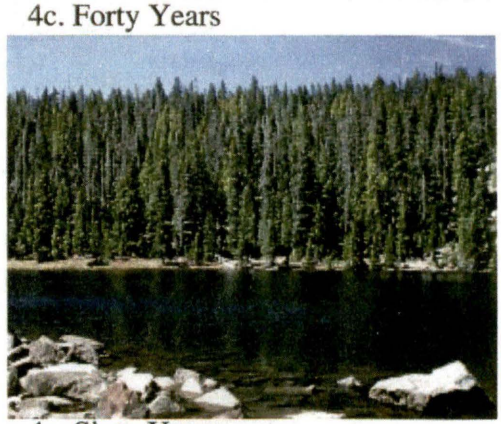


4b. One Year

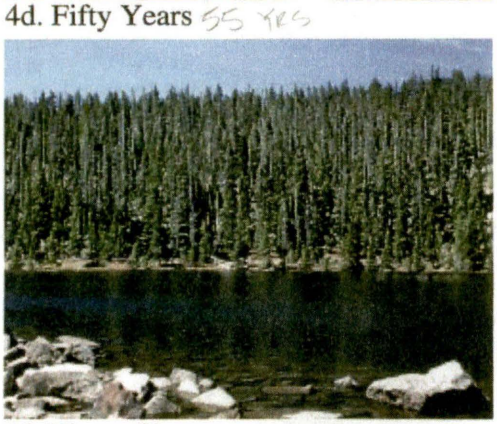


4c. Forty Years

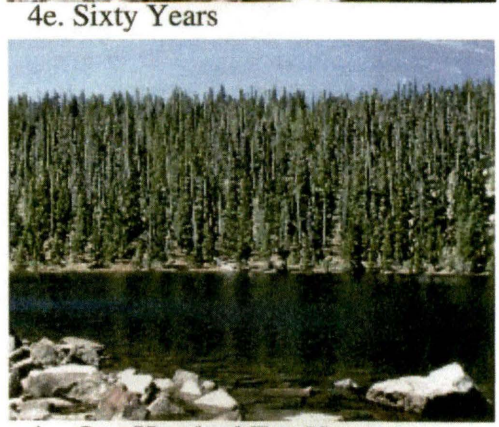
4d. Fifty Years 55 YRS



4e. Sixty Years



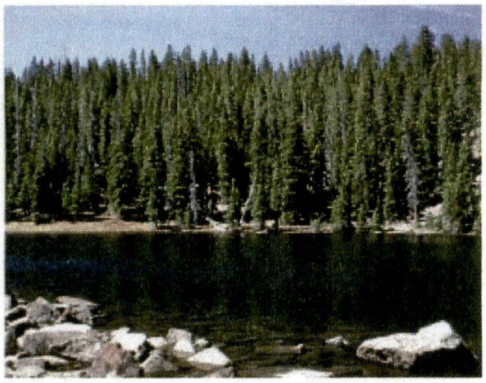
4f. Ninety Years



4g. One Hundred Ten Years

Surveyor's Lake - Plate 2A

Simulations show conditions in the forest after a spruce bark beetle outbreak was followed by management intervention actions. Individual tree selection thins to 110 sq. ft. of basal area on a thirty year cycle.

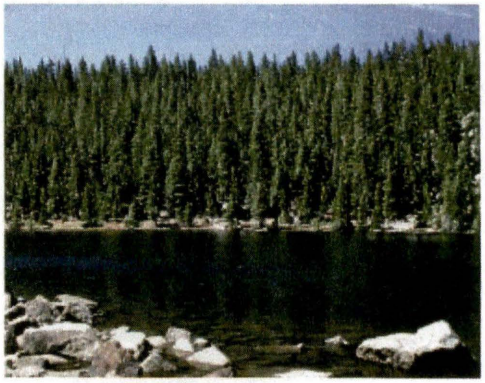


5a. Original Image (1991)

5b. One Year

5c. Fifteen Years

5d. Twenty Years



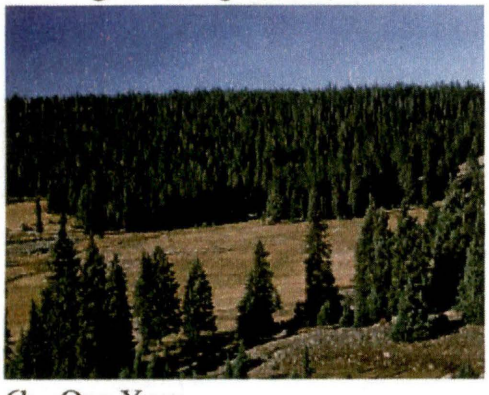
5e. Forty Years

5f. Fifty Years

Pleasant Creek - Plate 3A

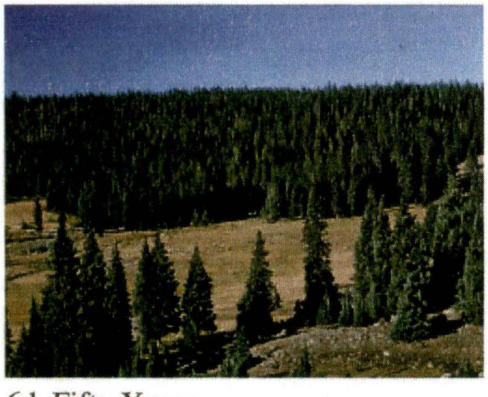
Simulations depict conditions as the forest recovers from a spruce bark beetle outbreak without management intervention. Through time the forest displays a yellow discoloration and the trees eventually turn to dead grey snags.

6a. Original Image (1991)

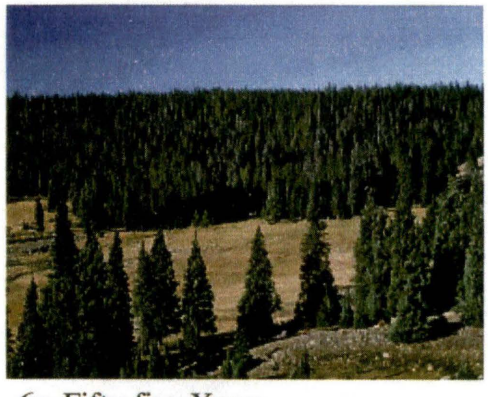


6b. One Year

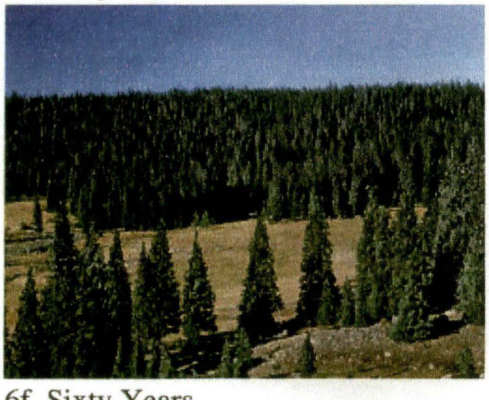
6c. Thirty Years



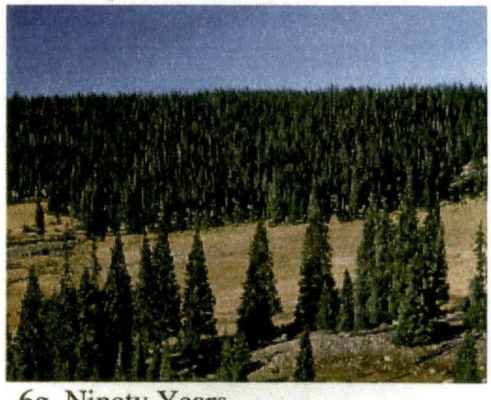
6d. Fifty Years



6e. Fifty-five Years



6f. Sixty Years



6g. Ninety Years

Pleasant Creek - Plate 3B

Simulations show conditions of the forest after a spruce bark beetle outbreak is followed by an individual tree selection thin to 110 sq. ft. of basal area on a thirty year cycle.

7a. Original Image (1991)

7b. One Year

7c. Fifteen Years

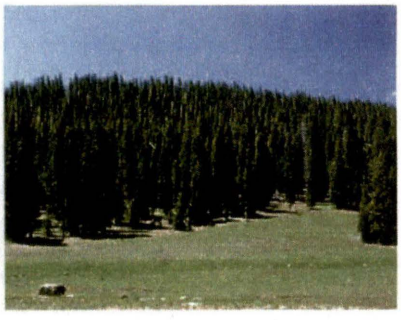
7d. Twenty Years

7e. Forty Years

7f. Fifty Years

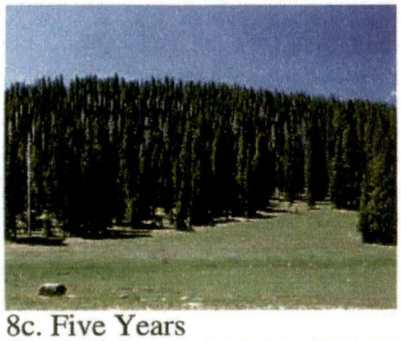
Midway Face - Plate 4A

Simulations show projections of the conditions following infestation without management intervention. The healthy green forest discolors to a yellowish color and eventually dead grey snags appear.

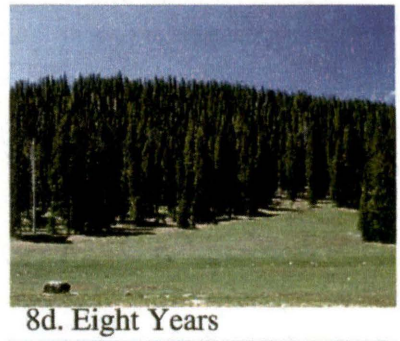


8a. One Year (1991)

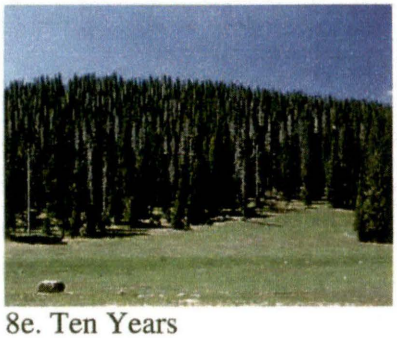
8b. Three Years



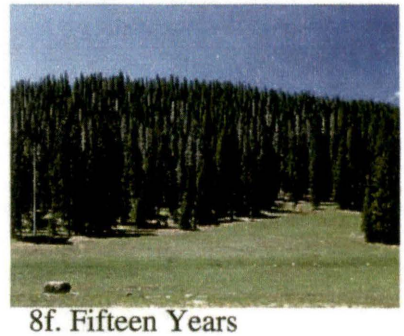
8c. Five Years



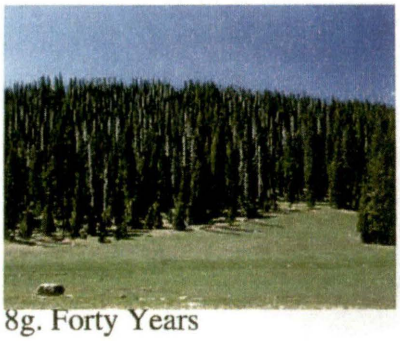
8d. Eight Years



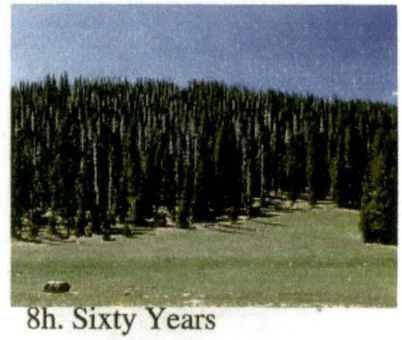
8e. Ten Years



8f. Fifteen Years



8g. Forty Years



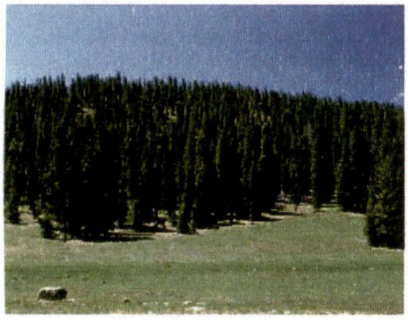
8h. Sixty Years

Midway Face - Plate 4B

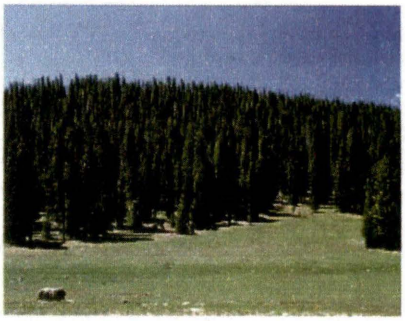
Simulations show conditions as the forest recovers following management strategy one. This strategy involves a sanitation thin by groups.

9a. Original Image (1991)

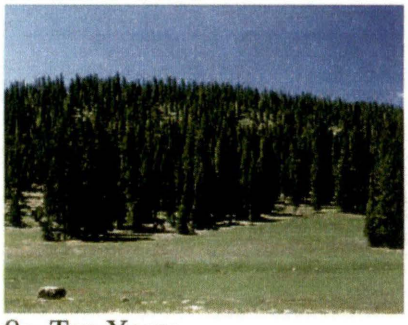
9b. One Year



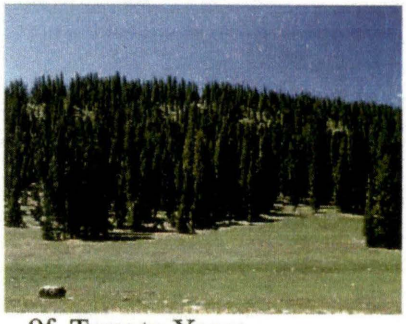
9c. Three Years



9d. Seven Years



9e. Ten Years



9f. Twenty Years

9g. Forty Years

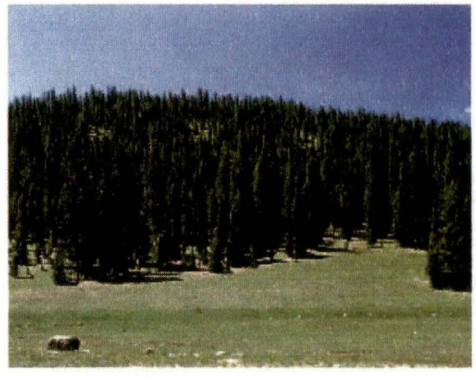
9h. Sixty Years

Midway Face - Plate 4C

Simulations show conditions as the forest recovers following management strategy two. This method of intervention involves an individual selection thin whereby damaged areas are removed and thinning to a 120 basal area occurs, on a forty year cycle.

10a. Original Image (1991)

10b. One Year



10c. Thirty-five Years

10d. Forty Years

10e. Seventy-five Years

A total of 67 subjects produced reliable responses in the *blocked* format condition. Although the same number of subjects was used in both conditions (i.e., subjects rated scenes in one of the *mixed* runs and then rated scenes in one of the *blocked* runs), a number of subjects did not produce reliable responses in this condition. Subjects were removed for not discriminating amongst the different levels of simulations (i.e., they gave the same ratings to all of the scenes within the same sequence). A breakdown of subjects by condition is provided in Table 4. All ratings were reordered and transformed into *Scenic Beauty Estimate* values using RMRATE.

RESULTS OF PREFERENCE STUDY

An initial concern with all studies of this type is the internal consistency of the responses from the respondent groups. As is usually the case the inter-rater reliability coefficients ranged from .77 to .931, high values indicating high consensus among subjects. This measure estimates the agreement between the test group and any other group drawn at random from the same population — perfect agreement would result in a coefficient of 1.00.

Another concern is that there should be strong agreement between groups on the evaluation of the same images, in this case the "baseline" images. Correlations of ratings of common scenes ranged from .647 to .749. Perfect agreement would be indicated by a correlation of 1.00.

These results are very much in line with those found in other, similar, studies. Furthermore, there is a substantial body of literature that confirms that such judgments based on color slide surrogates for the real settings would agree very closely with judgments made on-site in the photographed environments. Taking these findings together, the results reported here can confidently be generalized to the experiences of the typical forest visitor to these settings.

Scenic beauty perceptions

Boulder Mountain

The forest around Purple and Surveyor's Lakes and Pleasant Creek was heavily impacted by spruce beetle in the 1920s. At that time very high mortality was experienced accounting for almost all trees over 4" dbh. The forest now is in an advanced stage of

recovery from that outbreak with numerous of those surviving trees now over 16"dbh.

Purple Lake: The historic data reconstructed for Purple Lake, and the photos from 1948 and 1968, enabled the calibration of the forest development model and the visual simulation processes. The preference responses to the "reconstruction" images (Plate 1) followed an intuitively reasonable pattern (Table 6 and Figure 1), the initial, pre-outbreak image being highly rated, followed by a substantial drop in response to the extensive mortality, then a gradual rise as the forest recovers to its current condition. Patterns for projected future conditions were not so clear. Respondent ratings for the no-treatment condition also followed an intuitively reasonable path. At forty years from present the forest would reach very high stocking levels — undesirable to the forest manager — but the respondent response to such a uniform, dense, forest was to rate it quite highly. After an anticipated insect damage episode the situation after 45 and 50 years is quite different and very low ratings were observed. The treatment response projected to avoid this possibility was to reduce stand density by entries at 20-year intervals. The expectation would be that ratings would be higher at a point in time equivalent to that of greatest insect impact. However, this was not reflected in the results which followed an erratic path showing no immediately logical relationship to expected forest health conditions.

Year	**Retrospective**		**No Treatment**		**Treatment**	
	mean	sbe	mean	sbe	mean	sbe
-70	4.71	-2.53				
-65	3.86	-36.53				
-45	5.31	-4.37				
-25	5.29	9.68				
0	6.29	48.43				
1			5.97	38.81	6.59	51.29
15					6.65	57.77
20					5.69	8.59
40			6.65	53.4	6.29	55.84
45			5.13	-11.88		
50			4.75	-23.01	4.00	-32.25
90			5.29	22.94		
100			4.71	-13.33		

Table 6. Purple Lake, mean preference and Scenic Beauty Estimates

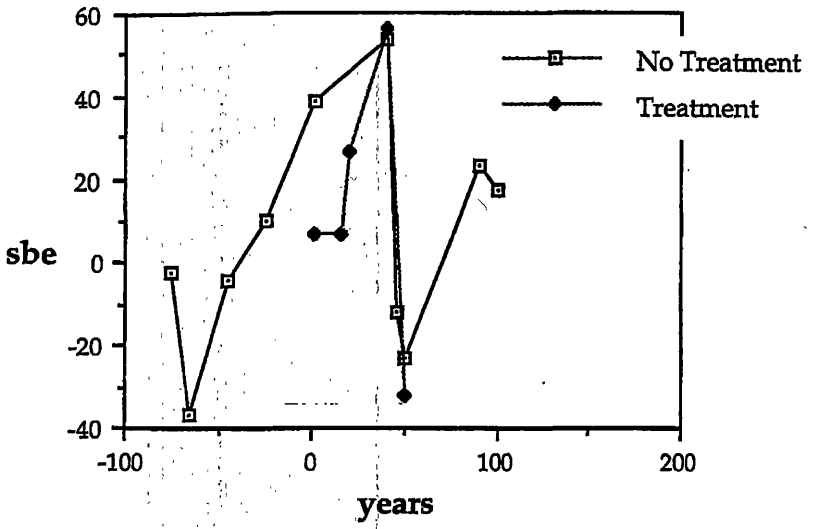


Figure 1. Purple Lake, respondent Scenic Beauty Estimates

Surveyor's Lake: The simulation processes used in representing changes on this site matched those used for the Purple Lake scene. Forest conditions at Surveyor's Lake closely matched conditions at the former location, although at a higher altitude. No treatment and a twenty-year treatment cycle were presented in the visualizations (Plate 2). The preference responses for this scene also followed an intuitively reasonable pattern (Table 7 and Figure 2). at the 11-year time horizon under the no-treatment condition there is little change in the forest condition. At forty years, however, the anticipated increase in stand density would result in a high probability of insect outbreak, resulting in the extensive damage represented here. Subsequently the recovering

Year	Retrospective		No Treatment		Treatment	
	mean	sbe	mean	sbe	mean	sbe
0	7.35	83.04				
1			7.21	82.4	7.19	65.3
11			7.41	79.74		
15					7.16	73.95
20					7.33	89.63
40			5.75	12.25	6.53	63.58
50					6.66	67.37
55			7.39	96.59		
60			7.47	97.72		
90			5.35	7.71		

Table 7. Surveyor's Lake, mean preference and Scenic Beauty Estimates

forest conditions resulted in rising levels of response.

The treatment condition represented a reduction of basal area at twenty year intervals, predicted to result in continuing forest conditions of low insect infestation hazard. Preference responses indicated a small initial drop in value followed by continuing high values.

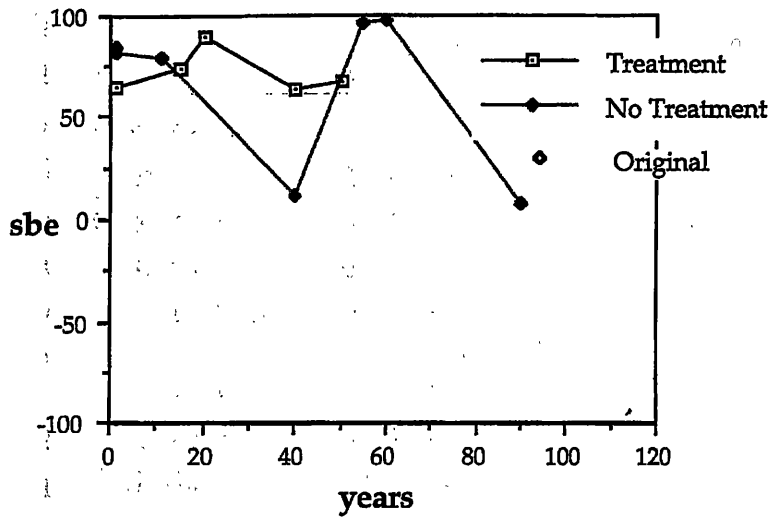


Figure 2. Surveyor's Lake, respondent Scenic Beauty Estimates

Pleasant Creek: Forest conditions at Pleasant Creek were similar to those at the last two sites. As with Surveyor's Lake this site is at high altitude and includes a spruce-fir mix forest. No treatment and a twenty-year treatment cycle were presented in the visualizations (Plate 3). The preference responses for this scene did not follow the intuitively reasonable patterns recognized for the first two scenes (Table 8 and Figure 3). At the 1- and 30-year time horizons under the no-treatment condition there was a marked change in forest condition represented in the simulations. Extensive mortality shown in images resulted in lowered preference responses but followed by some surprising increased values at the 50, 55 and 60-year stages.

As before, the treatment condition represented a reduction of basal area at twenty year intervals, predicted to result in continuing forest conditions of low insect infestation hazard. Preference responses indicated a small initial drop in value followed by a surprising drop in value, then followed by higher values.

Year	Retrospective mean	sbe	No Treatment mean	sbe	Treatment mean	sbe
0	5.04	-6.07				
1			4.56	-28.34	4.27	-27.15
15					5.18	-.35
20					4.5	-24.15
30			4.64	-12.55		
40					5.18	2.12
50			4.76	-6.33	4.72	-7.63
55			5.25	-4.96		
60			5.19	-10.3		
90			5.00	-17.08		

Table 8. Pleasant Creek, mean preference and Scenic Beauty Estimates

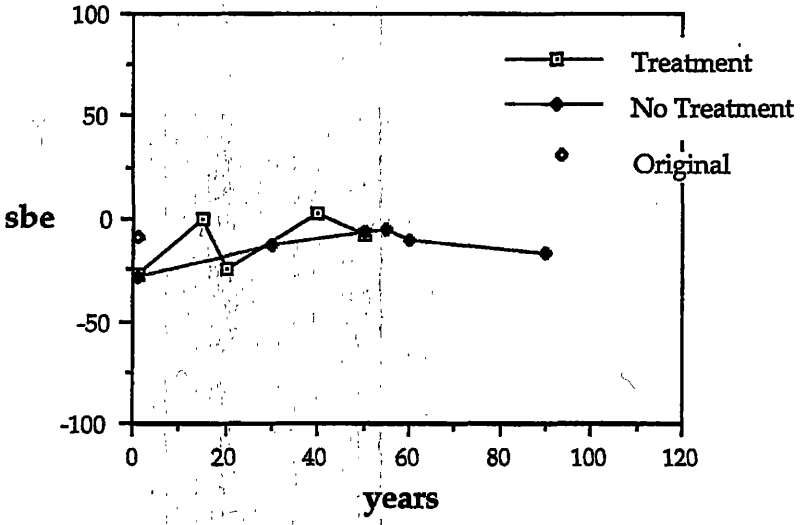


Figure 3. Pleasant Creek, respondent Scenic Beauty Estimates

Midway Face

At a lower elevation than the Boulder Mountain sites, this site is unique in having an active spruce beetle outbreak. Simulations of future conditions therefore assumed immediate evidence of damage in all conditions (Plate 4). The no-treatment condition indicated the increasing severity of insect damage followed by slow recovery. Treatment 1 included the removal of all insect-damaged trees at twenty-year entries but with no attempt to manage for reduced pest hazard. Treatment 2 represents more active response to high insect damage hazard. As well as removing all insect damaged trees, stand density is reduced in order to reduce insect hazard.

Preference responses respond to the alternative treatment patterns in reasonable ways (Table 9 and Figure 4). In the no treatment condition preference responses dip sharply as the extent and severity of insect damage increases. At forty and sixty years from present the recovery of the forest is reflected in an up-turn in preference responses. Treatment 1 responses follows the same general pattern as those for no-treatment. The appearance of, and persistence of, open patches in the forest results in continuing low preference ratings. Treatment 2 responses, however, do not decline to the level of the other treatments but remain at a high level for an extended time period.

Year	Retrospective		No Treatment		Treatment 1		Treatment 2	
	mean	sbe	mean	sbe	mean	sbe	mean	sbe
0	4.94	2.9						
1			4.53	-19.65	4.94	-14.84	5.00	-10.34
3			5.31	-3.84	4.24	-30.94		
5			5.06	3.64				
7					5.18	-2.86		
8			5.12	-13.28				
10			4.18	-27.89	3.86	-37.73		
15			3.56	-73.23				
20					3.5	-71.59		
35							4.29	-28.46
40			3.07	-63.18	4.35	-27.66	4.64	-7.65
60			4.18	-46.32	3.21	-64.17		
75							5.06	.19

Table 9. Midway Face, mean preference and Scenic Beauty Estimates

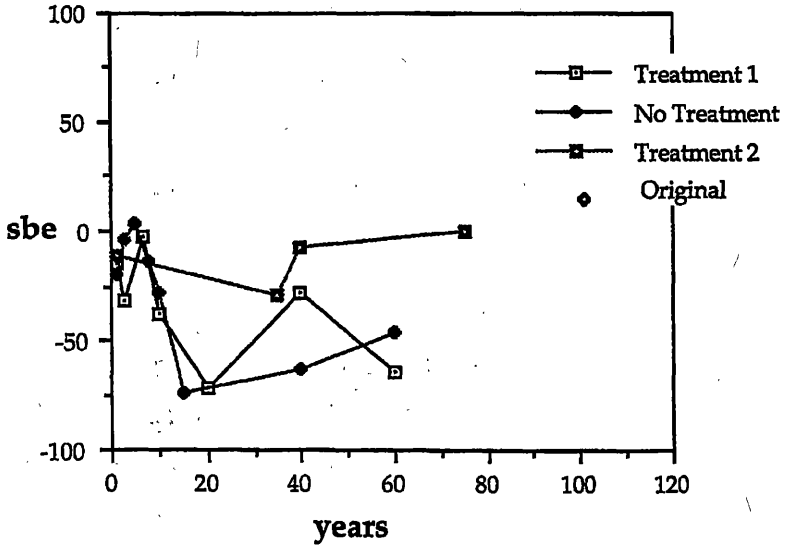


Figure 4. Midway Face, respondent Scenic Beauty Estimates

CONCLUSIONS

The use of computer visualization technology proved most valuable in communicating the anticipated effects of insect damage and treatment. Even in the confines of the agency office, the visualizations can assist in sharing notions of future forest conditions between different areas of expertise. In this instance it was shown to be feasible to take the output from standard forest growth and yield modeling and develop concrete visual representations to communicate those abstract numerical estimates. This study extends the progress reported by Daniel and Orland (1992) in visualizing spruce beetle impacts in Alaska by strengthening links between forest data and visualizations.

The assessment of the perceived effects of the spruce beetle outbreak and related mitigation measures on forest scenery revealed some consistent patterns. The patterns of responses closely followed the expectations of the forest scientists involved in the study as to their general positive or negative direction but with the benefit of being able to show magnitude relationships between the changes.

The scenic beauty of scenes decreased with mounting proportions of beetle killed trees. Responses to the impacts of mitigation measures were more negative for the dramatic and extensive management intrusions than for widespread but minimal levels of disturbance. However, response patterns were also sensitive to the reduced level of evident impact as the forest recovered. The biggest net benefits in scenic beauty accompanied the rehabilitation strategies that resulted in the faster recovery of forest condition to current levels. In this study a single medium, color slides, and a limited range of respondents (University of Arizona students) were used. However, previous experience with evaluations of Alaskan scenery indicate that such media and respondent pools are representative of the situations and populations for these studies (Daniel et al., 1992).

It was clear in the case of the Midway Face scenes that people preferred the long-term benefits of vigorously removing beetle-infested trees to ensure earlier eradication of the pest. The operationally more feasible but less vigorous removal of only already dead material would result in longer time to recovery and more threat of re-infestation, and hence lower perceived preference.

Two areas can be identified for further effort. First, while more progress has been made in linking numeric data and models with visual imagery there is still more opportunity

for integration of abstract and concrete representations of the forest resource. Other work in the Imaging Systems Lab. and using data collected on the Dixie National Forest, is experimenting with direct data-visualization links in an interactive computer environment. While the technology is currently quite sophisticated the next five years will see it widely distributed to forest managers.

Second, while the technological side of computer visualization is alive and well, the science of human-visual display interfaces is woefully inadequate. There are a small number of papers existent that address some of these issues (e.g., Vining and Orland, 1990; Bishop and Leahy, 1989) but as yet no overall framework or generalizable results. It is clear that research in this area is lacking and hopefully will emerge in the next few years.

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The Imaging Systems Laboratory

The Imaging Systems Laboratory was established in 1986. Activities concentrate on environmental perception research related to the visualization of environmental impacts, with emphases on methodological studies and on preference and choice modeling. The lab has been a pioneer in the use of computer visualization as a practice and research tool, and continues to lead in the integration of photo-realistic rendering tools with numerical modeling and remote sensing.

Equipment comprises two Silicon Graphics Indigo workstations -- one R4000 with Elan graphics, 32 Mb RAM, 1.5Gb Disk, the other an R3000, 24 Mb, 420Mb. Also MacII-fx, Quadra950, Centris650, two '486 PCs, color printers and film recorder. Software development has used C, C++ and the GL graphics library. The lab conducts a range of applications projects in the area of natural system visualization using PC and Macintosh platforms in addition to the SGI. Research budget is approximately $250,000 for 1992/1993.

Staff include a research manager, and eight student assistants. Assistants are drawn from many disciplines and are jointly supervised with faculty from Electrical and Computer Engineering, Computer Science, and Forestry. Research activity is collaborative with off-campus experts and faculty at other universities including Arizona, Alaska, Utah, Texas A&M, Wyoming, and Melbourne. Expertise represented includes Psychology, Marketing, Statistics, Sociology, Geography, Neuroscience, Entomology, and Ecology.

Year	Retrospective		No Treatment		Treatment	
	mean	sbe	mean	sbe	mean	sbe
-70	5.00	-15.72				
-65	4.3	-45.91				
-45	5.78	17.01				
-25	2.92	-87.52				
0	4.897	-15.656				
1			4.65	-23.72	5.605	14.735
15					5.41	3.076
20					4.59	-27.74
40			5.71	13.72	5.985	26.515
45			4.86	-25.45		
50			5.27	5.52	4.23	-42.18
90			3.75	-60.81		
100			3.11	-91.33		

Table 10. Purple Lake, mean preferences and Scenic Beauty Estimates, Blocked Data

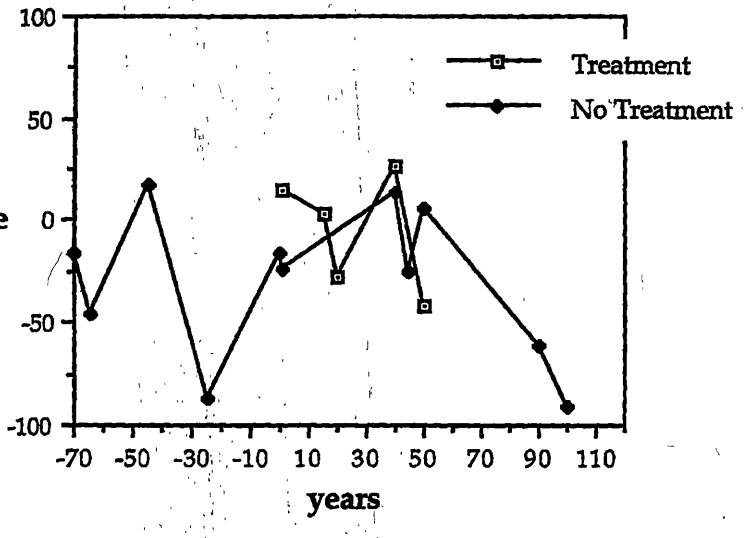

Figure 5. Purple Lake, respondents' Scenic Beauty Estimates, Blocked Data

Year	Retrospective		No Treatment		Treatment	
	mean	sbe	mean	sbe	mean	sbe
0	5.69	14.596				
1			5.526	10.893	5.95	24.825
11			4.28	-31.126		
15					5.33	-.92
20					7.23	84.28
40			7.17	78.106	7.15	71.20
50					7.03	70.13
55			6.93	66.55		
60			4.66	-17.33		
90			5.07	-3.43		

Table 11. Surveyor's Lake, mean preferences and Scenic Beauty Estimates, Blocked Data

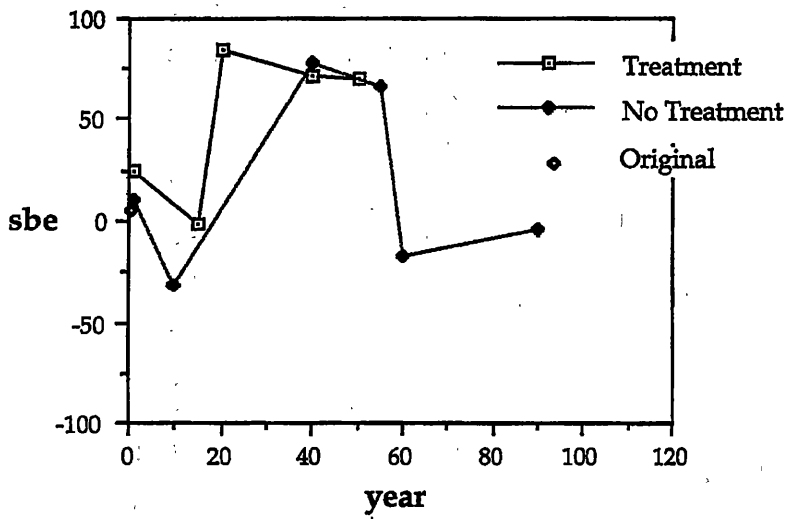

Figure 6. Surveyor's Lake, respondents' Scenic Beauty Estimates, Blocked Data

Year	Retrospect		No Treatment		Treatment	
	mean	sbe	mean	sbe	mean	sbe
0	6.05	32.72				
1			5.84	21.143	5.77	19.883
15					6.00	24.77
20					5.59	13.07
30			6.065	25.855		
40					5.64	16.25
50			6.04	30.92	5.756	16.203
55			4.91	-10.80		
60			3.635	58.5		
90			4.276	-32.55		

Table 12. Pleasant Creek, mean preferences and Scenic Beauty Estimates, Blocked Data

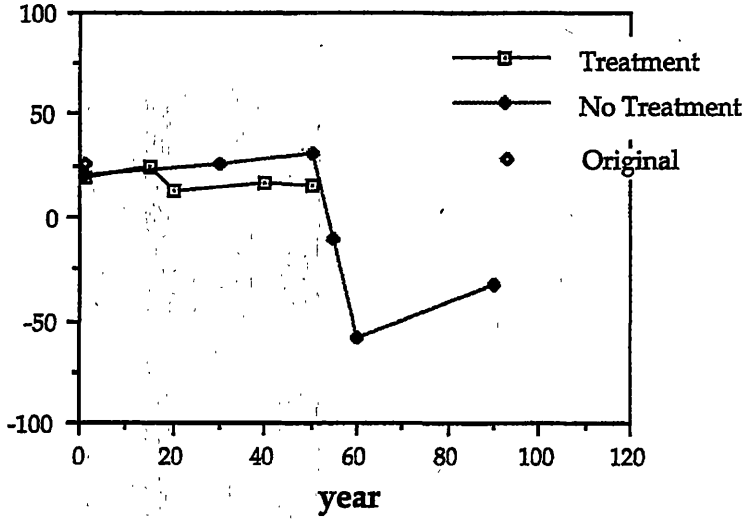

Figure 7. Pleasant Creek, respondents' Scenic Beauty Estimates, Blocked Data

Year	Retrospect		No Treatment		Treatment 1		Treatment 2	
	mean	sbe	mean	sbe	mean	sbe	mean	sbe
0	5.886	25.033						
1			5.573	9.843	5.896	25.443	5.23	-4.69
3			5.78	21.38	5.05	-3.16		
5			4.00	-56.19				
7					4.89	-13.15		
8			2.85	-89.33				
10			4.05	-37.59	4.44	-31.66		
15			5.00	-5.24				
20			4.15	-43.48				
35							4.703	-25.33
40			5.81	20.44	4.34	-38.275	5.07	-7.33
60			4.033	-39.266	4.86	-15.563		
75							5.68	8.93

Table 13. Midway Face, mean preferences and Scenic Beauty Estimates, Blocked Data

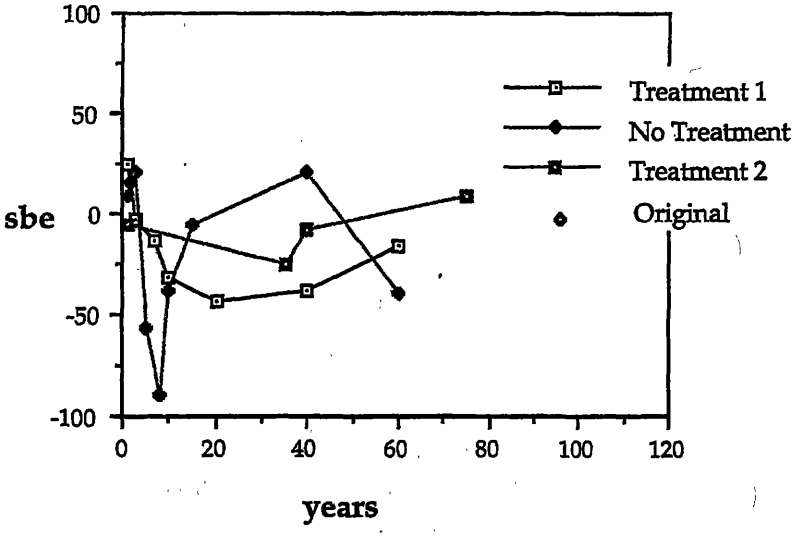

Figure 8. Midway Face, respondents' Scenic Beauty Estimates, Blocked Data

Video script: Dixie National Forest Project

What you are about to see are sets of these simulations based on the 4 study scenes.

****

The first set of images are of Purple Lake which is located on the west side of Boulder Mountain, in the Teasdale Ranger District, mid-slope at approximately 9,000 feet elevation.

The current basal area is 165 sq. ft. composed of 95% spruce species and 5% fir species.

Under a no treatment scenario, the following sequence of events is expected.

At one year, a few of the dead snags have dropped out.

Moving ahead 40 years, most of the dead snags are gone. Growth is evident throughout the stand with many of the openings now being filled in with new growth.

At 45 years, the visual evidence of damage begins as a yellowish-green coloration which is scattered throughout the stand in clumps, hitting mostly the older trees. About 20% of the larger trees are affected.

The damage which began at 45 years is now grey at year 50 along with additional damage beginning. Here, 20-30% of the larger trees are now dead and grey. An addi-

tional 30% have entered the first stages of damage. Most of the mortality is located in the mid-slope to foreground area where the larger trees are located.

At 90 years into the future, the damage appears as dead snags. Approximately 60-70% of the larger trees have been affected.

At 100 years , some additional damage has occurred and some of the dead snags have blown down. New growth has begun to fill in some of the bare spots.

A silvicultural treatment which includes individual tree selection thins to 110 sq. ft. of basal area on a 30 year cycle would produce the following scenario.

After one year, a few of the snags have dropped out.

At 15 years new growth has increased the density to approximately 146 sq. ft. of basal area.

At 20 years the treatment begins. One third of the basal area or about 1/4 of the trees are removed. Removal occurs uniformly throughout all size classes.

After 40 years additional growth now fills in spaces left by the treatment 20 years earlier.

At 50 years the area is to be thinned again down to 100 sq.ft.basal area. More of the larger trees are removed at this time.

For Purple Lake historic photos and records were available. These following scenes are a reconstruction of events from 1920.

In 1920 this was a healthy stand in much the same condition as today.

In 1925 a severe insect outbreak occurs and leaves 90% of the spruce species dead.

In 1948 the dead trees appear as snags in the landscape. Openings become apparent in the stand.

By 1968, some regeneration has occurred, but the dead snags still dominate the view.

****

The next set of images are of Surveyor's Lake. This is a high altitude lake at the north end of Boulder mountain at about 11,000 ft. elevation. The current basal area is 135 sq. ft.

Under a no treatment scenario the following sequence of events is expected.

At one year, a few of the old dead snags drop out.

At 40 years, most of the snags are gone and new growth is building up the density of the stand.

At 55 years mortality begins and groups of larger trees show first stages of damage as a yellowish-green coloration. Approximately 30% of the vegetation is affected.

At 60 years, the trees affected in year 55, along with an additional 30%, appear as grey snags. 20% are in the first stages of damage. A total of 80% have been attacked by spruce beetle.

At 90 years, all affected trees are now dead grey snags. Some scattered trees remain alive. Openings within the stand are created by the dead trees.

At 110 years , some snags have fallen creating open areas. Eventually, regeneration will occur in the these open areas.

A silvicultural treatment which includes individual tree selection thins to 110 sq. ft. of basal area on a 30 year cycle would produce the following scenario.

After one year, a few of the snags have dropped out.

At 15 years new growth has begun to increase the density of trees .

At 20 years the treatment begins. The stand is thinned to 110 sq. ft. of basal area. Tree removal is conducted uniformly throughout the stand.

After 40 years, additional growth fills in spaces left by the treatment 20 years earlier.

At 50 years, the area is to be thinned again from 162 to 100sq. ft.of basal area . More of the larger trees are removed at this time.

****

The following set of images is of Pleasant Creek which is in an open depression on the top of Boulder Mountain, facing east at approximately 11,000ft. The current basal area is 130 sq. ft.

Under a no treatment scenario, the following sequence of events is expected.

At one year some growth is evident in the foreground.

At 30 years, additional growth is evident in the foreground, some isolated trees are affected by the damage.

At 50 years, the evidence of the damage is widespread. Hits occur in groups where the

basal area is higher. Within each group, 40% of the trees have been affected.

At 55 years areas hit in year 50 are now grey with an additional 25-45% being currently attacked by bark beetle.

At 60 years, all of the affected trees are now grey with 40-50% dead. Some trees in the foreground are also affected.

At 90 years, dead trees now appear as snags. Openings are created by the dead trees and views into the stand are now apparent.

A silvicultural treatment which includes individual tree selection thins to 110 sq. ft. of basal area on a 30 year cycle would produce the following scenario.

After one year some growth becomes evident in the foreground..

At 15 years new growth increases the density of the stand.

At 20 years the treatment begins. The stand is thinned from 162 sq. ft. to 108 sq. ft. of basal area. Tree removal is conducted uniformly throughout the stand.

At 40 years, additional growth fills in spaces left by the treatment 20 years earlier. Growth is also evident in the foreground.

At 50 years, the area is to be thinned again from 169 to 110sq. ft. of basal area. More of the larger trees are removed at this time. Some regeneration is evident in the foreground of the stand.

****

This scene is of the Midway Face. It is located in the Cedar City Ranger District, along a shallow valley paralleling Utah Route 14. The study area faces north adjacent to the junction with Utah 143 from Cedar Breaks National Monument.

The current basal area is 200 sq. ft. composed of 70% spruce species ,17% fir species and 13% mortality.

Under a no treatment scenario, the following sequence of events is expected.

At 1 year, damage is presently occurring. Three small centers of damage exist with a few damaged trees scattered throughout the stand.

At year 3, the first year's damage has turned grey, while the current damage is spreading outward from the centers.

At year 5, damage continues to radiate out from the centers. The third year damage hits are now grey. Additional damage is scattered outside the main centers.

At year 8, the damage continues to spread. Older damage appears as snags.

At year 10, damage continues to spread, hitting the older spruce.

At year 15, damage is still spreading. Openings are evident in the foreground because of loss of density and trees falling.

At year 40, some dead snags along ridgetop have blown down and openings appear.

At year 60, regeneration that began in the foreground openings is now visible.

A silvicultural treatment which includes a sanitation thin of the currently damaged trees in groups, will produce the following scenario. The cutting is done on a ten year cycle.

At year one the current damage centers are evident.

At year three, the original centers of the damage are removed.

At year 7, larger areas are cut as damage radiates out from the centers.

At year 10, damage is still occurring.

At year 20, cuts continue to radiate out from the centers with some additional new cuts appearing.

At year 40, openings in the upper slope begin to fill in. The spread of damage has discontinued by this time.

At year 60, growth continues and the cut areas become less visible.

An alternate silvicultural treatment is also shown for this area. It combines the removal of currently damaged areas along with an individual selection thin conducted uniformly throughout the stand. Thinning occurs on a 40 year cycle.

At year one the currently damaged centers are removed in a group cut. The remainder of the stand is thinned by 40% of the basal area.

At year 35, the stand is gaining density and the pockets begin to fill in.

At year 40, the stand is thinned evenly down to 120sq. ft. basal area.

At year 75, the basal area has returned to approximately 180 sq. ft. and some of the openings in the foreground have filled in with regeneration.

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